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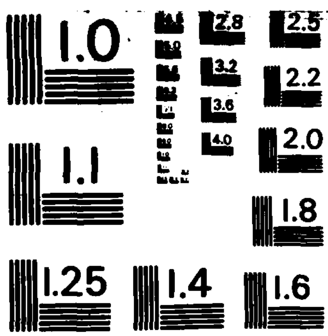

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A DESIGN AND CONSTRUCTION METHOD OF MOULDLESS POURED CONCRETE ARCH

by

Mou Chongrui

FOREIGN TECHNOLOGY DIVISION

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A Design and Construction Method of Mouldless Poured Concrete Arch

Mou Chongrui

Usually wooden mould plates are used in the construction of freshly poured concrete or steel reinforced concrete arches in underground engineering. In recent years, steel mould plates were also used. However, lumber and thin steel plate are difficult to obtain. Moreover, their costs are high and it is time consuming to fabricate, install, remove, and repair the moulds. In order to conserve timber and steel plate to reduce construction time, to accelerate progress, and to lower costs, the author adopted a construction plan which used 1 m long, 20 cm wide, and 6 cm thick pre-fabricated steel reinforced concrete slabs instead of mould plates in the construction of a 7 m net span concrete arch in a tunnel during last year. Pre-fabricated slabs were assembled into an arched plate. Concrete was poured over the arched plate. Steel bars sticking out of the slab were closely bonded to the freshly poured concrete to form a solid arch. Because the fabrication environment for the pre-fabricated slabs is good and can be verified conveniently, their quality can easily be insured. No. 200 concrete was used for pre-fabricated slabs and No. 150 concrete was used for the freshly poured portion. The strength of the composite would not be lower than that of No. 150 concrete. Such pre-fabricated slabs not only replaced mould plates but also became a permanent load-bearing structural element. It is not only required to increase the thickness of the originally design concrete arch but also will not weaken the strength of the design. All the visitors, who saw the 459 m^2 of freshly poured concrete arch already completed, believed that the result was impressive. A neighboring outfit was prepared to design and construct a civil defense project according to this method.

DESIGN OF PRE-FABRICATED SLAB

The width of the pre-fabricated slab must be compatible with the radius of curvature of the arch (which was 4 m). The thickness and length should be based on convenience for installation and transportation. The author designed the pre-fabricated slab to be 1 m long, 20 cm wide, and 6 cm thick. Each slab weighed 30 kg. Load design: it was calculated according to an arch concrete thickness of 0.5 m (actually 0.4 m), which included the weight of the pre-fabricated slabs $q_1 = 1.25$ ton/m^2, construction load $q_2 = 0.2$ ton/m^2; $q = q_1 + q_2 = 1.45$ ton/m^2. The axial spacing of the arch was the length of the slab, L = 1 m. The concrete was No. 200*. To facilitate the calculation and table finding, the slab width was chosen to be 1 m (i.e., width of 5 slabs). $M = (1/8)ql^2 = (1/8) \times 1.45 \times 1^2 = 0.181$ ton.m. After looking up page 46 of the steel reinforced concrete structure calculation manual, it was found $A_g = 2.48$ cm^2/m. If 10Ø6 was chosen (2Ø6 for each plate), then $A_g = 2.83$ cm^2/m > 2.48 cm^2/m. The steel bars distributed all over were chosen to be 4Ø4.

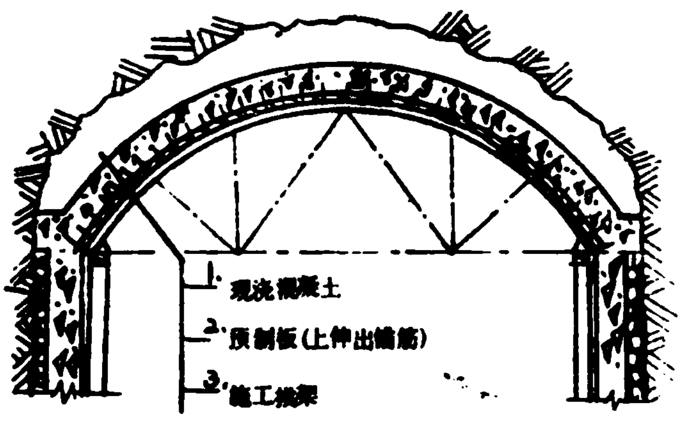

Figure 1. Schematic Diagram of Replacing Mould Plates With Pre-Fabricated Slabs

1. freshly poured concrete
2. pre-fabricated slabs (with steel bars sticking out)
3. construction stage

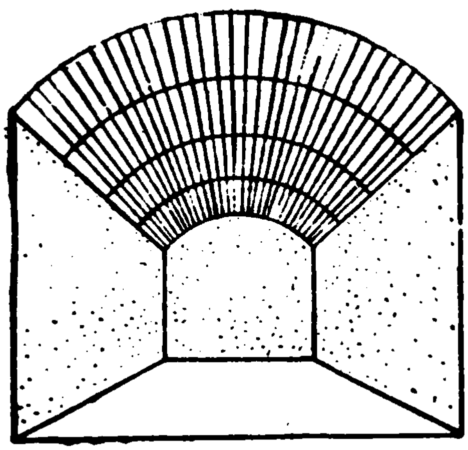

Figure 2. Perspective Drawing of Pre-fabricated Slab Vault

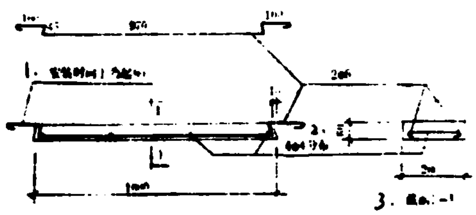

Figure 3. Distribution of Steel Bar on a Pre-fabricated Slab

1. bending 90° upward when installed
2. 4Ø4 distribution
3. cross-section 1-1

FABRICATION OF PRE-FABRICATED SLAB

Because steel reinforcing bars were only distributed on one side of the pre-fabricated plate, the reinforcing steel mesh was necessarily placed on the bottom when the concrete was poured. However, the bottom happened to be the surface of the vault. The lack of a clean finish would affect the indoor beauty. Usually the pre-fabricated plate is turned around after reaching a certain strength and its surface is smeared once more. However, not only is it time consuming but also the bonding is not tight. If the reinforcing mesh is placed on top, although concrete pouring and surface finishing can be done simultaneously, the position of the mesh will easily sink when the poured concrete is firming up. Thus, quality cannot be ensured.

In order to ensure the quality of a pre-fabricated slab, to facilitate its fabrication, and to improve efficiency, the author assisted the construction unit in the design and fabrication of a rotating mould. By using such a mould, concrete pouring and surface cleaning could be carried out simultaneously. Furthermore, the position of the reinforcing bars could be completely assured.

The structure and operating method of the rotating mould are briefly described in the following: The two long frames of the mould L were made of L60 x 5 angle steel 1.2 m in length. A small section of L60 x 5 angle steel was welded to each end to form a hollow square steel bar. The function is to invert but not tilt the side frame L when the mould is turned around. The two side frames were made of flat steel 5mm thick and 6 cm wide; welded to form an oblique groove. The width was 20 cm, which was the width of the pre-fabricated slab. Notches were cut at places where the reinforcing bars were sticking out. The bottom plate was nailed together by a 140 x 40 x 3 (cm) wooden plank. Two parallel wooden bars spaced at a distance equal to the long frame L were nailed onto the bottom plate. The two long frames L and short frames were placed between the two wooden bars. The two ends were secured with Ø10 steel clamps to form a model of the pre-fabricated slab. The details are shown in the

structure scheme of the pre-fabricated slab mould.

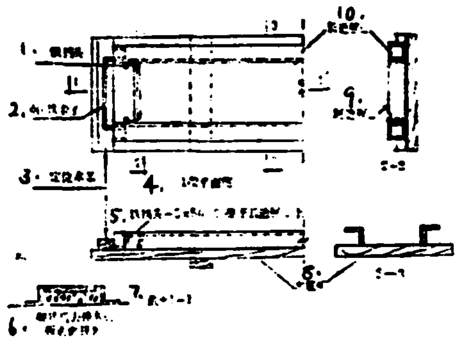

Figure 4. Schematic Diagram of the Structure of Rotating Mould for Pre-fabricated Slab

1. iron lip
2. iron clamp
3. positioning wooden bar
4. 1/2 plane
5. iron lip - 5 x 50 x 20 equal to long frame
6. remove bottom plate after turning around and finishing slab surface
7. cross-section 1-1
8. wooden bottom plate
9. short frame
10. long frame

After placing reinforcing mesh in the mould, pouring concrete and firming by ramming, the mould was immediately turned around, and placed flat on the ground. The bottom plate was removed. The surface was first finished. The clamps and frames were then removed, and a pre-fabricated slab was made and ready to be started all over again. The fabrication was very simple and convenient.

INSTALLATION OF PRE-FABRICATED SLAB

Pre-fabricated slabs were installed on an arched frame. When the arched frame was erected, the middle span spacing was 1 m. The side span spacing was 0.9 m to prevent loss of stability due to pressure.

When the arched support frame was secured, the pre-fabricated slabs were laid down from the two legs towards the vault. The first slab had to be laid down straight against the wall in cement. The remaining slabs were arranged in orderly fashion and the seams were filled with 1:2 cement to sand paste. The pre-fabricated slabs were made into a solid arched slab. To ensure the safety of poured concrete and to prevent leakage, sand, stone, and dirt on the pre-fabricated slabs were washed away by water after the cement was dried and before concrete was poured. The freshly poured concrete was able to bond tightly to the pre-fabricated slabs to become a single structure to take on the load.

This technique is not only applicable to underground engineering but also to surface engineering such as single curvature arched bridges and culverts.

ADVANTAGES OF USING PRE-FABRICATED SLABS INSTEAD OF MOULD PLATES

1. Conserve lumber or steel plate (mould plate).

2. The fabrication and installation of pre-fabricated slabs are simple and easy. It eliminates the mould removal process. Because the arched slab once assembled has a certain load bearing capability, the duration for the removal of the arch support can be greatly reduced. Furthermore, the support can be conveniently taken apart without suffering from any damage. Therefore, the turn around rate is very high, which accelerates the construction speed.

3. The surface of the vault is neat, clean, and good looking. Because of the formation of crossing lines in a regular pattern, the dull feeling of a smooth vault does not exist. Moreover, reflected sound is scattered so that there is some silencing effect.

4. Conserve manpower and materials to lower engineering

costs. In the past, a lot of work was involved in the fabrication, installation, removal, repair, brushing with soap water or waste oil of wooden moulds used in the concrete pouring of vaults. According to a summary of a previous construction project, the manpower involved in the wooden mould was 50.7% of the total labor. According to the regulation, the overall man-day for pouring concrete on an arch is 4.97 per m^3. Then, the wood moulds consume 4.97 man-day/m^3 x 50.7% = 2.5 man-day/m^3. When the concrete vault thickness is 0.4 m, the labor involved in the moulds is 2.5 man-day/m^3 x 0.4 m = 1 man-day/m^2.

When pre-fabricated slabs are used instead of wooden moulds, the labor involved in the fabrication and installation is (7.43 + 1.67) man-day/m^3 x 0.06 m = 0.546 man-day/m^2, according to the same calculation by referring to items 3-7-49 and 3-7-50 (fabrication and installation of staircase steps). Because pre-fabricated slabs are used, 0.06 m less concrete needs to be poured, which saves 4.97 man-day/m^3 x 0.06 m x 49.3% = 0.147 man-day/m^2. This should be subtracted from the labor for the fabrication and installation of pre-fabricated slabs, i.e., 0.546 - 0.147 = 0.399 man-day/m^2. Here one can see that pre-fabricated slabs require 0.601 man-day less than wooden moulds for each m^2, i.e., saving 39.9% in labor. Moreover, the installation of pre-fabricated slabs is much faster than the installation of staircase steps.

The reinforcing steel bars used in pre-fabricated slabs are also cheaper than the lumber consumed in wooden moulds for concrete pouring. Because of differing lumber prices, it is very difficult to figure out an exact amount. The reader can calculate it by the difference in the consumption of steel and wood and the cost differential. In summary, both manpower and materials can be saved by using pre-fabricated slabs, consequently lowering engineering costs.

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